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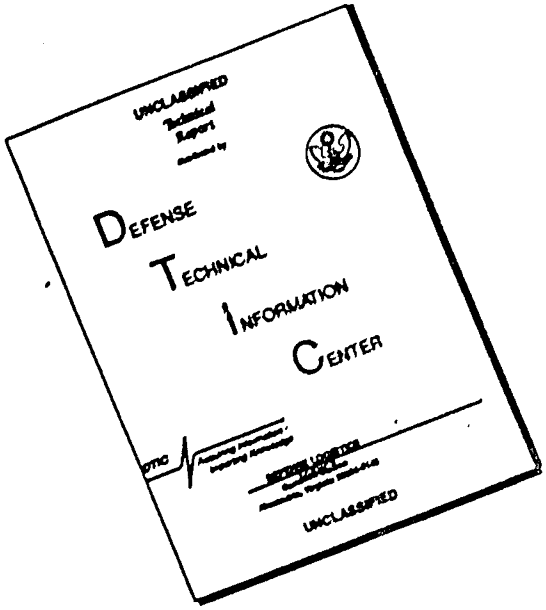

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ERRATTA

8 March 65

FINAL REPORTS OF THE
WEAPON SYSTEM EFFECTIVENESS INDUSTRY ADVISORY COMMITTEE (WSEIAC)

AFSC-TR-65-1

AFSC-TR-65-2 (Vols I, II & III)

AFSC-TR-65-3

AFSC-TR-65-4 (Vols I & III)

(Note: This Errata sheet applies to each of the above reports.)

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Atch 2

WEAPON SYSTEM EFFECTIVENESS

INDUSTRY ADVISORY COMMITTEE (WSEIAC)

FINAL REPORT

of

TASK GROUP II

PREDICTION - MEASUREMENT

(SUMMARY, CONCLUSIONS AND RECOMMENDATIONS)

FOREWORD

This is Volume I of the final report of Task Group II of the Weapon System Effectiveness Industry Advisory Committee (WSEIAC). It is submitted to the Commander, AFSC in partial fulfillment of Task Group II objectives cited in the committee Charter. The final report is contained in three separate volumes:

> Volume I Contains an overview of Task Group II findings, including a summary of Volumes II and III, conclusions, and recommendations.
>
> Volume II contains a discussion of effectiveness concepts, a description of specific tasks required to evaluate effectiveness, and a detailed example illustrating the method.
>
> Volume III contains descriptions of effectiveness analysis methods applied to four typical Air Force systems using the techniques described in Volume II.

The membership of Task Group II was as follows:

Mr. D. F. Barber (Chairman)	RADC (EMER)
Mr. I. Bosinoff	Sylvania Electronics System Division
Mr. I. Doshay	Space General Corporation
Dr. B. J. Flehinger	IBM - Thomas J. Watson Research Laboratories
Mr. W. Haigler	Rocketdyne - Division of North American Aviation, Inc.
Mr. H. J. Kennedy	ARINC Research Corporation
Mr. C. R. Knight (Technical Director)	ARINC Research Corporation
Mr. A. J. Monroe	TRW Space Technology Laboratories
Mr. M. H. Saunders	OOAMA (OONEW)
Mr. I. M. Tall	Radio Corporation of America
Mr. H. D. Voegtlen	Hughes Aircraft Company

Other task group reports submitted in fulfillment of the committee's objectives are

AFSC-TR-65-1	Final Report of Task Group I "Requirements Methodology"
AFSC-TR-65-3	Final Report of Task Group III "Data Collection and Management Reports"

AFSC-TR-65-4	Final Report of Task Group IV "Cost-Effectiveness Optimization"
AFSC-TR-65-5	Final Report of Task Group V "Management Systems"
AFSC-TR-65-6	Final Summary Report "Chairman's Final Report"

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

APPROVED

William F. Stevens

William F. Stevens, Colonel, USAF
Chief, Systems Effectiveness Division
Directorate of Systems Policy
DCS Systems

WSEIAC CHARTER

In order that this report of Task Group II may be studied in context with the entire committee effort, the purpose and task group objectives as stated in the WSEIAC Charter are listed below:

Purpose

The purpose of the Weapon System Effectiveness Industry Advisory Committee is to provide technical guidance and assistance to AFSC in the development of a technique to apprise management of current and predicted weapon system effectiveness at all phases of weapon system life.

Task Group Objectives

Task Group I - Review present procedures being used to establish system effectiveness requirements and recommend a method for arriving at requirements that are mission responsive.

Task Group II - Review existing documents and recommend uniform methods and procedures to be applied in predicting and measuring systems effectiveness during all phases of a weapon system program.

Task Group III - Review format and engineering data content of existing system effectiveness reports and recommend uniform procedures for periodically reporting weapon system status to assist all levels of management in arriving at program decisions.

Task Group IV - Develop a basic set of instructions and procedures for conducting an analysis for system optimization considering effectiveness, time schedules and funding.

Task Group V - Review current policies and procedures of other Air Force commands and develop a framework for standardizing management visibility procedures throughout all Air Force commands.

ABSTRACT

Concepts of system effectiveness measurement and prediction, presented in detail in Volume II, are summarized briefly in this volume. Eight formalized tasks necessary to evaluate effectiveness are reviewed. Summaries of four illustrative examples, presented in detail in Volume III, are given. These examples provide useful guidelines for effectiveness evaluation at various phases of system life cycle. Conclusions concerning the present state of system effectiveness evaluation are presented. A series of recommendations are proposed for Air Force adoption.

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TABLE OF CONTENTS

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SECTION I

INTRODUCTION AND SUMMARY

1. Task Group II Objective

The original objective of Task Group II is summarized as follows:

> "Review existing documents and recommend methods and procedures to be applied in predicting and measuring effectiveness during all phases of a program."

2. Products of the Group

In fulfillment of the above objective, Task Group II prepared a series of three Volumes described below:

> Volume I is a summary of the technical content of the remaining two volumes and is addressed to program management personnel and higher. It contains a consolidated list of recommendations and conclusions.

> Volume II is a detailed exposition, by example, of the recommended mathematical framework in which it is proposed that system effectiveness be computed/measured. It is addressed to project level personnel and is intended to provide a working knowledge of the proposed mathematical methods.

> Volume III presents detailed analyses of four Air Force systems: airborne avionics, ICBM squadron, radar surveillance, and spacecraft. The intent of the examples is to provide detailed guidance in utilizing the proposed mathematical framework.

SECTION II

DISCUSSION

1. Background

The high cost and complexity of modern military systems require the most efficient management possible to avoid wasting significant resources on inadequate equipment.

Efficient systems management depends on the successful evaluation and integration of numerous different but interrelated system characteristics such as reliability, maintainability, performance and cost. If such evaluation and integration is to be accomplished in a scientific rather than intuitive manner, a method must be formulated to assess quantitatively the effects of each system characteristic on overall system effectiveness. It is such a method which Task Group II of WSEIAC was directed to prepare.

2. System Life Cycle Considerations

AFR 375-1 divides the life cycle of a system into the Conceptual, Definition, Acquisition and Operational Phases. The results obtained from the evaluation in each phase will differ both in accuracy and in intended use.

During the Conceptual Phase, the predicted effectiveness of various types of systems proposed to meet an operational need will be a critical factor in selecting the optimum course of action to follow. A limited amount of data will be available at this phase, so effectiveness predictions will be based largely on experience with previous systems.

Effectiveness models generated during the Definition Phase will be useful in determining the configuration and scope required of a system. More accuracy will be possible than was inherent in the Conceptual Phase as enough detail will be available to employ such techniques as "Prediction by Function" in assigning values to the characteristics comprising system effectiveness.

During the Acquisition Phase, systems effectiveness predictions can be employed to determine the inherent capability of the proposed system to achieve its required effectiveness, the effects of proposed changes on systems effectiveness, and the optimum trade-off of system characteristics. Because much more will be known of the system, and actual tests will be performed, the accuracy of systems effectiveness predictions will be much higher than in the preceding phases.

Finally, in the Operational Phase, it will still be necessary to employ prediction techniques to evaluate systems effectiveness. Actual field measurements will be performed, but these will apply only to peacetime conditions. These measurements must be utilized in a systems effectiveness prediction model to indicate the capability of the system to perform its design mission in a state of war. During this phase the prediction will be most accurate as many system characteristics may be measured. Complete accuracy will never be possible short of war, as such essential items as enemy strategy will not be completely known. A highly accurate prediction of systems effectiveness under given hypothetical environments will, however, be possible.

3. Review of Volume II

a. Concepts

In Volume II, system effectiveness has been defined as a measure of the extent to which a system may be expected to achieve a set of specific mission requirements. It is further defined to be a function of the system's availability, dependability, and capability.

Availability is a measure of the system condition at the start of the mission. It is a function of the relationships among hardware, personnel, and procedures.

Dependability is a measure of the system condition at one or more points during the mission, given the system condition(s) at the start of the mission.

Capability is a measure of the ability of a system to achieve the mission objectives, given the system condition(s) during the mission. Capability specifically accounts for the performance spectrum of a system.

The usefulness of a mathematical representation (model) of the above factors and the steps essential to the model's construction and its use in system evaluation are discussed in some detail. These steps include the specific tasks which must be undertaken in order to provide the necessary model inputs. These also require the analyst to itemize the conditions imposed and the assumptions made in performing the evaluation.

b. Task Analysis

System effectiveness evaluation/prediction can be reduced to an ordered set of tasks as follows:

(1) Mission Definition
  - Functional description of purpose
  - Quantitative requirements

(2) System Description
  - General configuration
  - Block diagram
  - Time line analysis

(3) Specification of Figures of Merit

(4) Identification of Accountable Factors
  - Level of accountability
  - Personnel characteristics
  - Procedure characteristics
  - Hardware characteristics
  - Logistics
  - Data constraints

(5) Model Construction
  - Assumptions
  - Delineation of possible mission outcomes
  - Delineation of significant system states

(6) Data Acquisition
  - Specification of data elements
  - Specification of test methodology
  - Specification of data reporting system

(7) Parameter Estimation

(8) Model Exercise

- Numerical evaluation of effectiveness and its factors
- Comparative system analysis
- Parameter variation study

The examples of Volumes II and III adhere rather closely to this analysis of the steps required to achieve a system effectiveness evaluation/prediction.

c. Analytical Methods

A specific, analytical model is introduced in which Effectiveness is expressed as the product of availability, dependability, and capability. In order to provide for the treatment of the various conditions of the system, each of the three variables is expressed as a vector or a matrix. This method of mathematical representation and treatment has the advantage that it methodically considers all significant states of the system and their contributions to mission success, and permits a proper consideration to be given to the contributions to mission accomplishment of "less-than-perfect" system conditions.

In the various sections of Volume II dealing with the determination of the vectors and matrices, the construction and application of sub-models is discussed. These sub-models are required to determine the numerical values of the elements of the vectors and matrices. While several typical sub-models are discussed -- and employed in sample evaluations -- it was not possible in the time allotted to show all sub-models which might be employed in the evaluation of any system.

In highly complex systems, realistic assumptions relating to the accountable factors often make the analytical formulation of Availability (A), Dependability (D), and Capability (C) matrices impractical. When this is the case, the only feasible course is to resort to either analog or digital computer simulation.

Simulation methods available are so numerous and varied that it is impractical, here, to give a preferred method. The best method in a particular case depends on the nature of the system, the phase of the program, and the precision required. For example, in some cases it may be desirable to use simulation methods only to provide estimates of the A, D, C matrix elements; in other cases it may be preferable to by-pass the intermediate outputs and proceed directly to an overall measure of effectiveness.

Despite the possible variations, all simulation methods for estimating effectiveness have some fundamental common characteristics. First, the relations between accountable factors and the effectiveness figure of merit must be mathematically described; second, the manner in which the accountable factors may vary from one system trial to another must be known or reasonable assumptions established; and third, a large number of repeated system trials must be run on the computer, using randomly selected values from the statistical distribution of the accountable factors, to obtain the resulting system's degree-of-success. This last step is commonly referred to as a Monte Carlo procedure.

Simulation techniques, like analytical methods, can be used to determine the sensitivity of the system figure-of-merit to variations in the accountable factors. In such an exercise, deliberate (rather than random) changes are introduced to the expected values of the accountable factors or to the parameter values of the distributions, and the Monte Carlo process is repeated.

In Volume II the use of simulation techniques is illustrated through application to a specific effectiveness problem.

4. <u>Review of Volume III</u>

Effectiveness evaluation for large Air Force systems is a complex task, subject to many variations in detailed procedures depending upon the type of system, information available to support the evaluation, and the phase of the system life cycle treated. In Volume III of the Task Group II report, a preliminary analysis of the utility of the evaluation methods proposed has been made, using several systems as hypothetical effectiveness vehicles. These exercises could not reasonably be expected to surface and answer all questions that might occur during actual evaluations; however, they <u>have</u> indicated some typical problems and suggested solutions.

A detailed description of the application of effectiveness evaluation procedures is given for the following four (4) examples:

(1) The avionics system in a tactical fighter-bomber;
(2) a squadron of intercontinental ballistic missiles;
(3) a fixed radar surveillance and threat evaluation system; and
(4) a spacecraft system.

In addition to the variety of system types included, an attempt is made to illustrate procedures employed at different phases of the system life cycle.

Further, each example is intended to illustrate, to a different level of detail, various aspects of the evaluation. The avionics system example, for instance, shows the possiblity of combining independent evaluations of several subsystems. The radar example shows simplifications which can be made in order to minimize the number of system states to be considered. In the ICBM example, illustrations of many of the detailed procedures required to evaluate components of the vectors and matrices are shown. Finally, the spacecraft example shows techniques for determining elements of the Dependability matrix.

These examples do not illustrate all possible methods of application and use of the evaluation procedures. Rather, they are intended to show applicable methods of application, areas of flexibility, and uses which might be made of the evaluations.

a. Airborne Avionics System Example

The purpose of this example is to demonstrate how the effectiveness evaluation techniques proposed by Task Group II may be applied to the avionics system of a tactical fighter-bomber aircraft. The example considers only the "bombing" function. Similar analyses could be made for its "fighter," "ground support," etc., functions.

It is assumed that the effectiveness evaluation is being made during the Program Definition Phase of system life. Similar evaluations in the real world would also be necessary for system configurations established during the Acquisition and Operational Phases. A major consideration of the Program Definition Phase is "force structure," i. e., the number of systems (aircraft) required to accomplish a specific mission. The example illustrates how the results of the effectiveness evaluation aid in making tradeoffs and ultimate decisions.

The svstem is evaluated as a tactical weapon. The aircraft is considered to be deployed at an advanced base in the theater of operations, and is called upon to bomb tactical targets in enemy territory. It is assumed that no enemy offensive action will be mounted against the advanced base.

At any random time when an execution order is received, the aircraft shall take off immediately, receive a target assignment, proceed to target area, deliver weapon within 500 feet of target, and return to assigned operation base.

b. <u>ICBM Fleet Example</u>

It is the specific object of this example to illustrate the analysis of an ICBM fleet in terms of the formal mathematical structure adopted by Task Group II of the Weapon System Effectiveness Industry Advisory Committee. In particular, the analysis illustrates the usefulness of models in assessing the impact of potential system alterations.

The general requirements of this hypothetical system may be stated as follows:

Any missile of the ICBM fleet should be ready to accept a launch directive at a random point in time, or at an arbitrary time after an alarm condition has been established at a random point in time. It should then launch successfully within a prescribed reaction time, fly a ballistic trajectory, penetrate enemy defenses, arm, fuse, impact within the prescribed target area, detonate and yield as planned with a prescribed probability of target destruction.

Minimum acceptable and objective numerical system requirements for availability, countdown, flight, and probability of kill are postulated in the form of an SOR.

c. Radar Surveillance System Example

This example illustrates for this type of defense sytem the effectiveness prediction techniques discussed earlier in this document. The tasks required to evaluate system effectiveness have been considered throughout the four phases of system life, and the increasing amount of detail which is necessary as the system evolves is shown.

The requirements of this system are:

(1) Detect airborne objects in the surveillance sector at a range of not less than 3,000 nautical miles.

(2) Identify the objects, and determine within 30 minutes whether or not they constitute a threat.

d. Spacecraft System Example

This example illustrates in some detail a method by which Dependability of a spacecraft may be determined from conservative estimates of hardware reliability. This approach is suggested in the absence of large amounts of test data on the vehicle being evaluated. This usually occurs during the Program Definition and early system Acquisition Phases of programs on substantially new systems. It is also useful for evaluating extremely costly systems of which only a few are to be constructed. No effort is made in this example to treat availability or capability, beyond illustrating their tie-in with Dependability to calculate effectiveness.

The assumed purpose of this evaluation is the determination of critical elements in the proposed spacecraft configuration.

The spacecraft system shall be capable of placing a variety of payloads, including multiple satellites, into precise orbits about the earth. It shall have the capability of restarting in space after a sufficient coast period dependent on the specific payload and attitude orientation in space. The system shall be designed as an upper stage rocket propulsion vehicle.

SECTION III

CONCLUSIONS

1. The results attained by Task Group II constitute a highly useful framework for system effectiveness decision making and evaluation. The examples presented in the report show that it is possible to employ this framework in a variety of system types. However, it was not possible in the time allotted to analyze and evaluate all existing procedures for treating each of the elements involved in effectiveness. Therefore, no recommendations could be made for specific, detailed techniques applicable to each type of system.

2. System effectiveness, as defined by Task Group II, represents a combination of system characteristics of major importance to the user. The definition proposed is felt to be sufficiently broad to be applicable to all system types at all stages of system development. It does, however, restrict consideration to the ability of the system to accomplish a specified mission. It does not, therefore, include such factors as cost or development schedule. These factors, and their trade-off with effectiveness, have been treated by Task Group IV.

3. System effectiveness is susceptible to both measurement and prediction. However, because it is generally not feasible to measure a system's effectiveness under the actual conditions of intended use, the element of prediction is always contained to some extent in the general effectiveness evaluation.

4. A general mathematical model has been developed which expresses effectiveness as a function of three major system characteristics, i. e., <u>Availability</u>, <u>Dependability</u>, and <u>Capability</u>. Each of these characteristics is defined so that the basic concepts intended to be treated by each are expressed. They are expressed, however, such that considerable flexibility in the methods of treating the concepts is permitted. The general model is of such a form that the influence on mission accomplishment of all system "states" (modes of degraded system operation) can be considered.

5. The eight-step procedure presented outlines a series of tasks which must be accomplished in order to evaluate the effectiveness of any system. Again, the procedure states the points which must be treated, yet permits considerable flexibility in the methods of treatment.

6. Using the procedures and mathematical model developed by Task Group II, effectiveness predictions can be made at all phases of the system life cycle. In the Conceptual Phase, the prediction will be based on experience with systems of similar type, and should be contained in the SOR. As the system proceeds through the Definition Phase, the availability of system design data will allow predictions to be made on the basis of equipment or subsystem function. During the Acquisition and Operational Phases, data derived from actual equipment or subsystem exercise, first under laboratory conditions and later in the field, will permit early predictions to be verified and modified where required in the light of more current experience.

7. Validation of effectiveness evaluation techniques should be accomplished on one or more AF systems, prior to implementation of the evaluation program contractually. An expansion of this subject will be given in recommendations to follow.

8. No consideration has been given to methods and procedures for effectiveness demonstration. Contractual specification of a quantitative effectiveness requirement must be accompanied by clearly stated test and demonstration procedures.

9. Specification of an effectiveness number in contractual documents should include specification of any constraints on the individual effectiveness characteristics (A, D, C) resulting from operational considerations. Contractual trade-offs would be permitted only within these constraints.

10. Figure(s)-of-merit developed must be interpreted in light of data limitations and assumptions. An expression of the analyst's confidence in the results should be given along with the numerical values.

11. Step-by-step techniques for using effectiveness evaluation in decision-making are required. This requirement includes such subjects as trade-offs, effects of corrective actions and sensitivity analyses.

12. Comprehensive generic data sources, especially those including effects of environmental stresses, are currently nonexistent. This is the weakest link in the chain of effectiveness prediction at the present time.

13. Improved techniques are required for conversion of available data to vector and matrix elements of A, D, C.

14. Present data collection and analysis on operational weapon systems is inadequate. This problem should be partially solved by implementation of Task Group III recommendations.

15. Additional research is required on the simulation approach to effectiveness evaluation for complex systems.

16. The elements and terms used in system effectiveness prediction and evaluation are in need of clear definition and standardization.

SECTION IV

RECOMMENDATIONS

1. The proposed analytical framework and system effectiveness concepts should be accepted as an initial working base.

2. The proposed effectiveness evaluation techniques and task analysis should be validated on one or more AF systems, covering each of the four (4) phases of the system life cycle. It is recommended that system(s) in the early Operational Phase be chosen for the validation exercise, and through recourse to system reports, files and other documentation, the evaluations for the earlier phases be synthesized. Although it will be difficult to maintain objectivity in such a synthesis it is felt that the obvious time advantage and the continuity provided justify the attempt.

3. Evaluation techniques should be modified in accordance with results obtained in (2) above.

4. The minimum validation program indicated should be completed before implementing effectiveness evaluation procedures contractually.

5. A study of procedures for test and demonstration of effectiveness, similar to those outlined for reliability in MIL-R-27070 and MIL-STD-781 should be initiated.

6. Further study is recommended on the entire question of "confidence" (quantitative or qualitative) in results of effectiveness evaluations, both in combining the confidence regions for the estimates or product functions and in guiding the decision process when no quantitative confidence statement is possible.

7. It is recommended that work on decision algorithms for application to incentive fee contracts be initiated. Methods for establishing incentive fee versus level of effectiveness as well as the associated subject of producer's and consumer's risk should be explored in detail.

8. The preparation and adoption of standard terminology and notation for system effectiveness should be accomplished at an early date.

The following recommendations are identified with certain of the specific tasks required to predict effectiveness:

9. Mission Definition

   It is recommended that the effectiveness requirement specified in the SOR be accompanied by a complete description of conditions under which this requirement must be met. It should be noted that operational requirements as specified in the SOR must be translated faithfully into contractual technical program objectives.

10. System Description

   There should be a series of contractually required, controlled documents completely describing the system at each point in time from the earliest stages of design to fully operational hardware.

   a. These documents should have a USAF approved distribution list and should be furnished to all cognizant branches and agencies of the USAF.

   b. The documents should be capable of rapid update, so as to depict the status of the system in near real time.

11. Data Acquisition

   a. Due to the wide disparity in quoted failure rates for similar components, it is recommended that a single authoritative source for collection, analysis, validation, and dissemination of this type of information be established. Steps should be taken immediately to establish the regulations, standards, or other control documents needed to assure the availability of component failure rate data.

   b. At the present time, there is no recognized source for maintenance data and checkout and repair times by equipment or function. It is recommended that such a source be established.

12. Parameter Estimation Techniques

The problem of estimation is a difficult one at best. The application of maximum likelihood, least squares, Bayesian statistics and sequential analysis, to name a few, are only cursorily treated in the Task Group II report. It is recommended that the USAF support a program to accomplish at least the following:

a. Survey of methods of estimation

b. Survey of cases of methodology validation.

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13. ABSTRACT

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